Aging and Life Analyses of Generation 2 Advanced Technology Development Lithium-Ion Cells

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The U.S. Department of Energy (DOE) initiated the Advanced Technology Development (ATD) Program in 1998 to help find solutions to technical barriers limiting the development of high-power lithium-ion batteries for hybrid electric vehicles. The intent of the testing portion of the ATD program is to characterize the performance and to determine the cycle life and calendar life behavior of lithium ion cells (1). A primary goal is to quantify power fade as a function of calendar time. Phase II (dubbed Gen 2) of the testing is now underway. This phase includes testing of a baseline cell chemistry and up to three variants (2).

The Gen 2 cells are concurrently being tested at the Idaho, Argonne, and Sandia national laboratories. In general, the cells are being subjected to the performance and life test procedures that have been defined for the Partnership for a New Generation of Vehicles (PNGV) program (3). Life testing consists of the 25 Wh Power Assist pulse profile cycle life test and the pulse-per-day calendar life test. Prior to commencing life testing, receipt inspection and characterization tests were performed on all the cells. The cells are 18650-size with a rated capacity of 1.0 Ah.

Every four weeks, the cells are taken off life testing for reference performance tests (RPT) consisting of a C1 static discharge and a low-current Hybrid Pulse Power Characterization (L-HPPC) test. Following the RPT, a select number of cells also undergo a C25 static discharge and an Electrochemical Impedance Spectroscopy (EIS) test before being sent to diagnostics.

Figures 1 through 3 show early results for representative individual baseline cells. Figure 1 shows the EIS Nyquist plot. Changes of the first semicircle with aging are related to growth in a thin film solid electrolyte (SEI) layer on the anode and/or cathode. Figure 2 shows a plot of differential capacitance [(1/Q)d(Ah)/dV] versus cell voltage calculated from a C/25 discharge and charge test. Peaks are thought to be related to specific intercalation sites within the anode and/or cathode. It has been postulated that the degradation of cell performance with aging is related to the change in the amplitude and location of these peaks. Figure 3 shows the available energy as a function of discharge power scaled to a full-size PNGV battery. As testing progresses, the growth in resistance and the fade in power, energy, and capacity are used to model cell performance and predict cell life. At the completion of testing, the aged cells are being sent to the Argonne, the Lawrence Berkeley, and the Brookhaven national laboratories for further diagnostic evaluation.

References

1. Advanced Technology Development, 1999 Annual Progress Report, U.S. DOE, OAAT, March 2000.
2. C. G. Motloch, J. P. Christophersen, et al., "Performance and Life Evaluations of Generation 2 Advanced Technology Development Lithium-Ion Cells," Electrochemical Society 199th Meeting, Washington DC, March 25-29, 2001.
3. PNGV Battery Test Manual, Revision 3, DOE/ID-10597, February 2001

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Figure 1. 60% SOC EIS Impedance at 5 mV

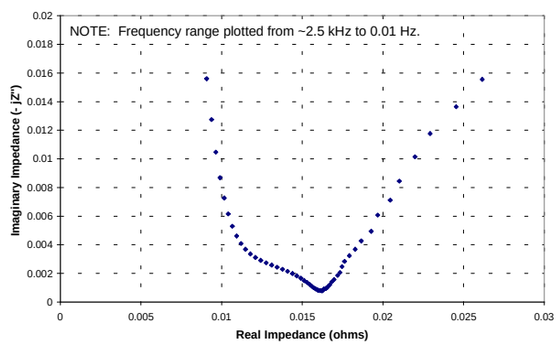

Figure 2. Characterization Differential Capacitance

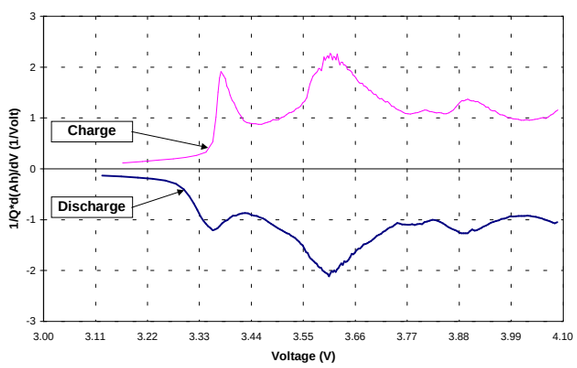

Figure 3. Available Energy vs Pulse Power Capability from L-HPPC Test